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Physicochemical and Bacteriological Analysis of Reservoir Water in Ksusta

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Abstract

This research work was carried out to determine the bacteriological and physicochemical quality of reservoir water. With the view of evaluating the physicochemical constituent of the reservoir water, we carried out the microbiological analysis of the water sample, and determined the total coliform count of the reservoir water. The physicochemical analysis was carried out using standard methods; the physicochemical analysis revealed that the reserve water samples have slightly acidic to neutral pH, varying conductivity, and acceptable alkalinity and TDS levels. However, the bacteriological analysis indicates the presence of coliform bacteria in all samples, with MPN values exceeding acceptable limits. These findings suggest that the reserve water may pose health risks if consumed without proper treatment. Physicochemical analysis showed pH (6.9-7.1), conductivity (156.1±3.72 - 184.7±9.58 µS/cm), alkalinity (8.0-8.2), and total dissolved solids (117.1±7.62 - 120.4±2.23 mg/L) within acceptable limits. However, bacteriological analysis revealed the presence of coliform bacteria in all samples, with most probable number values exceeding acceptable limits (21-28). In conclusion, the reserve water's physicochemical parameters are acceptable, but bacteriological contamination poses health risks. Regular monitoring and treatment are necessary to ensure the water's safety for consumption.

Keywords: bacteriological analysis; coliform bacteria; physicochemical properties; reservoir water; water quality.

Abbreviations: Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Kebbi State University of Science and Technology, Aliero (KSUSTA), Butylated Hydroxytoluene (BHT).

INTRODUCTION

Water is essential to urban and rural life and remains one of humanity's most valuable natural resources (Adimalla et al. 2019). It is required for domestic, agricultural, and industrial purposes and is one of the basic necessities of life. Although more than 70% of the earth's surface is covered by water, only a small proportion is suitable for human consumption (Alaya and Salhi 2017). Water is an important component of all living cells and is essential for life on earth (Ahmad et al. 2020). Adequate water supply is necessary for human development and socioeconomic activities (Gholson et al. 2007). Sources of water include rainwater, surface water such as rivers, streams, lakes, and ponds, and groundwater sources (Anthonj 2017).

Because water acts as a universal solvent, it dissolves various inorganic and organic substances that participate in metabolic reactions, nutrient transport, thermoregulation, and maintenance of body homeostasis (Akrong et al. 2019). Unsafe drinking water can contain physical, chemical, biological, and radiological contaminants that pose serious health risks (WHO 2024). The increasing demand for freshwater due to population growth places significant pressure on available water resources and creates challenges in maintaining water quality (Berk and Freedman 2011). Waterborne diseases caused by pathogenic microorganisms are commonly transmitted through contaminated water and constitute a major public health concern worldwide (WHO 2008).

Approximately 1.8 billion people still rely on unsafe drinking water sources contaminated by fecal matter, resulting in diseases such as cholera and typhoid fever (Botkin and Keller 2005). Waterborne diseases are transmitted through the ingestion of contaminated water, with water serving as a vehicle for pathogenic microorganisms (WHO 2010). Therefore, regular assessment of water quality is essential to ensure the safety of drinking water supplies. The safety of water depends largely on its physical, chemical, and bacteriological properties. In areas with limited municipal water supply, reservoir water often serves as

the major source of water for domestic use. However, improper location of reservoirs, inadequate waste disposal practices, and poor maintenance may contribute to water contamination.

In many parts of Nigeria, recommended standards regarding the location and protection of water sources are often not fully observed. The reservoir water in Kebbi State University of Science and Technology, Aliero serves as an important source of water for students and staff. However, contamination from surrounding activities, inadequate waste management practices, lack of proper treatment, and limited monitoring may compromise its quality. Therefore, routine evaluation of the physicochemical and bacteriological quality of the reservoir water is necessary.

The aim of this study was to determine the physicochemical and bacteriological quality of reservoir water in Kebbi State University of Science and Technology, Aliero. Specifically, the study aimed to evaluate the physicochemical characteristics of the water samples, carry out microbiological analysis, and determine the total coliform count of the reservoir water.

MATERIALS AND METHODS

Study Area

The study was conducted in Kebbi State University of Science and Technology Aliero, Aliero Local Government Area, Kebbi State. The area is located on latitude 12°18'30" N and longitude 4°29'30" E – 4°30'0" E at an altitude of 48 m above sea level (Adamu 2010). The local government in general is bounded in the Northeast by Gwandu Local Government Area, in the Southeast by Jega Local Government Area, in the East by Tambuwal Local Government Area, and has a population size of 125,785 inhabitants according to the 2006 census (Uzondu 2008). The topography of the area is flat and high undulating with compact stony brown soil. The climate is characterized by heavy fog and dust as well as relative cold. The mean annual temperature varies considerably but usually stands at about 42°C; however, March and April are usually the hottest months (Uzondu 2008). Most of the people in Aliero Local Government Area are agrarians with emphasis on vegetables, especially onions and pepper. The town has the largest onion market in Northwest Nigeria and serves as a major producer of onions in Nigeria.

Sampling Sites

The water samples were collected from two sources. Sampling sites were labelled A and B, with A representing classes and B representing the hostel in the university.

Figure 1. A Schematic Image of Hostel and classes Reservoirs

Sample Collection and Processing

Water samples were collected from reservoirs located at different places (sample A hostel, sample B classes) respectively, using sterile 250-mL capacity sampling bottles. All water samples were collected at the point representative of the sampling sites and were transported to the laboratory for microbiological analysis within 30 minutes of collection (i.e., the microbiology laboratory of the institute of Kebbi State University of Science and Technology Aliero). Physicochemical analysis was conducted in the chemistry laboratory while the bacteriological analysis was conducted in the microbiology lab.

Physicochemical Analysis

The physicochemical parameters of the water samples were determined using standard methods as described by Tareq et al. (2013).

Determination of pH

Twenty milliliters (20 mL) of each water sample was weighed into a 50 mL beaker and 20 mL of distilled water was added, stirred with a glass rod, and allowed to stand for 30 minutes. A digital pH meter was inserted into each water sample solution and the measurement was recorded (ASTM 2019).

Determination of Temperature

The temperature of the water samples was determined by the use of a mercury thermometer. The thermometer was allowed to equilibrate and the readings were recorded immediately in degrees Celsius (°C) (ASTM 2019).

Determination of Electrical Conductivity

Conductivity of the water sample was measured using a digital conductivity meter (HACH). The meter was initially switched on and then standardized using 0.1 N KCl at 25°C. The electrode was immersed into each of

the water samples and the conductivity reading of each sample was recorded (Kingsley et al. 2010).

Determination of BOD

The water sample was pipetted into a BOD bottle containing 20 mL of water sample. The initial dissolved oxygen content was determined and recorded, and the bottle was incubated in the dark for five days at 20°C. At the end of five days, the final dissolved oxygen content was determined and the difference between the final reading and the initial reading was calculated. The decrease in dissolved oxygen is corrected for sample dilution and represents the biochemical oxygen demand of the sample (Kingsley et al. 2010).

Determination of DO

DO in the collected water samples was determined with Winkler's method. The Winkler method involves trapping the DO in the water sample by reacting it with a series of reagents resulting in the formation of an acid compound in the presence of iodine. The iodide solution was then titrated with an appropriate neutralizing reagent. The change in color signifying the endpoint is equivalent to the quantity of DO in the water sample (Kingsley et al. 2010).

Media Preparation

The media that were used for this analysis were prepared according to the manufacturer's instructions as described by Akrong and Amu-Mensah (2019).

Presumptive Test

The test was carried out by means of tube inoculations, whereby sets of three test tubes with 10 mL of lactose broth each were used and inoculated with 10 mL of water sample (double-strength broth) and also 1 mL and 0.1 mL of water sample (single-strength broth). Using sterile pipettes, 1 mL of water samples was dispensed into sets of three tubes containing 10 mL of sterile single-strength lactose broth; another 0.1 mL of water samples was dispensed again into three tubes containing 10 mL of sterile single-strength lactose broth; 10 mL of each sample was also dispensed into a set of test tubes containing 10 mL of sterile double-strength lactose broth. Each fermentation tube contained an inverted Durham tube. The tubes were incubated at 37°C for 24–48 hours. After incubation, the results were recorded by looking for the presence of trapped gas/bubbles inside the Durham tube, which indicates a positive result. The MPN of coliforms in 100 mL of the water sample was estimated by the numbers of positive tubes and the results were checked on the MPN tables (Kingsley et al. 2010).

Confirmed Test

A loopful of the sample from positive tubes was transferred onto a plate containing Eosin Methylene Blue (EMB) agar medium by the streaking method and was incubated at 37°C for 24 to 48 hours. The agar inhibits Gram-positive organisms and allows the Gram-negative coliforms to grow. Coliforms produce colonies with dark centers, green metallic sheen, or large pinkish colonies (Kingsley et al. 2010).

Completed Test

The colonies developed from the confirmed test medium were inoculated onto Nutrient Agar slants in McCartney bottles using a sterile wire loop. This was then incubated at 37°C for 24 hours. After the incubation period, a smear of the isolates was made, Gram stained, and used to identify the morphology of bacteria that grew on EMB agar. A positive test indicates that coliforms are present in the water sample when the test shows Gram-negative, non-spore-forming rods (Kingsley et al. 2010).

Total Coliform and Fecal Coliform Count

The Most Probable Number (MPN) method was used to estimate the total and fecal coliform count in the water samples. This method is based on the detection of gas production in lactose broth during the serial dilution process. The number of positive tubes in different dilutions was used to estimate the MPN of coliforms per 100 mL of water according to APHA (2017) standards. The presence of fecal coliform bacteria, particularly *E. coli*, was confirmed using EMB agar, and the results were compared against drinking water quality guidelines provided by the World Health Organization (WHO 2017).

Smear Preparation and Gram Staining

Preparing a smear of colonies isolated from the agar surface was performed on a glass slide using a sterile wire loop. Two loopfuls of water were placed on the slide using an inoculating needle, mixing a very small quantity of the colony with the water and spreading it over the slide. It was allowed to air dry prior to heat fixation. The fixation was done by passing the slide over the flame of a Bunsen burner two or three times using a slide holder. The fixed smear was flooded with crystal violet solution for 30–60 seconds, rinsed with water, followed by Lugol's iodine for 60 seconds, decolorized with alcohol, and rinsed with distilled water (APHA 2009).

Gram staining technique is considered a standard microbiological identification method based on Gram reaction, originally developed by Hans Christian Gram in 1884. Smears were prepared, heat-fixed, flooded with crystal violet for 1 minute, washed, flooded with Lugol's iodine for 60 seconds, washed, decolorized with acid-alcohol, counterstained with safranin for 60 seconds, rinsed, and allowed to air dry.

Microscopy

A drop of immersion oil was added on top of the smear on the slide and a light microscope was used to examine the smear under the 100× objective lens.

Data Analysis

The data obtained from the physicochemical and bacteriological analyses were organized and presented in tables. Physicochemical parameters such as temperature, pH, electrical conductivity, total dissolved solids, biochemical oxygen demand, nitrate, and alkalinity were expressed as mean ± standard deviation (Mean ± SD). The total coliform counts obtained from the bacteriological analysis were determined using the Most Probable Number (MPN) method, and the MPN values were estimated using standard MPN tables. The frequency of occurrence of bacterial isolates was calculated as percentages using the formula: Frequency (%) = (Number of occurrences of an isolate / Total number of isolates) × 100. The results obtained were compared with the World Health Organization (WHO) guidelines for drinking water quality to determine the suitability of the reservoir water for domestic consumption.

RESULTS AND DISCUSSION

Physicochemical Analysis Results

The physicochemical parameters analyzed include temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), biochemical oxygen demand (BOD), nitrates (NO3-), and alkalinity, as shown in Table 1.

Table 1. Physicochemical characteristics of the Reservoir water in KSUSTA.

Parameter	Result (Mean ± SD) Sample A (Classes)	Result (Mean ± SD) Sample B (Hostel)	WHO Standards / Guidelines
Temperature (°C)	27.0 ± 0.15	25.2 ± 0.10	No specific limit; 25°C recommended for drinking water quality
pH	6.9 ± 0.06	7.1 ± 0.08	6.5 - 8.5
Electrical Conductivity (µS/cm)	156.1 ± 3.72	184.7 ± 9.58	1,500 µS/cm
Total Dissolved Solids (TDS) (mg/L)	117.1 ± 7.62	120.4 ± 2.23	500 mg/L
Biochemical Oxygen Demand (BOD) (mg/L)	6.3 ± 0.05	5.3 ± 0.08	<3 mg/L
Nitrate (NO3-) (mg/L)	0.2 ± 0.03	0.2 ± 0.06	10 mg/L
Alkalinity (mg/L)	83.3 ± 15.24	8.2 ± 1.10	100-200 mg/L (recommended for drinking water quality)

Explanation of Standards: Temperature: There is no fixed WHO guideline for temperature, but water above 25°C can affect its taste and may promote microbial growth. Alkalinity: The recommended alkalinity for drinking water is between 100-200 mg/L. However, values below this range are not necessarily harmful but indicate a lower buffering capacity of the water.

Bacteriological Analysis of KSUSTA Reservoir Water

The bacteriological quality of Kebbi State University of Science and Technology Aliero reservoir water was analyzed using the Multiple Tube Fermentation (MTF) technique with lactose broth. Durham tubes were inverted inside the test tubes to detect gas formation, indicating the presence of coliform bacteria. The samples were incubated at 37°C for 24–48 hours, and gas formation was observed in all tubes. After incubation, serial dilutions were performed, and the contents of the tubes were streaked on Eosin Methylene Blue (EMB) agar plates to isolate coliform bacteria.

Table 2. Total coliform plate counts (Average Colony Count).

Sample Type	EMB Plate 1	EMB Plate 2	EMB Plate 3	Total Colonies	Average Colony Count
Sample A (Classes)	30	30	30	90	30
Sample B (Hostel)	30	35	35	100	33.3

Sample A showed an average colony count of 30 colonies per plate, while Sample B had an average of 33.3 colonies per plate.

Most Probable Number (MPN) Determination

The bacteriological results were further analyzed using the Most Probable Number (MPN) method. The number of positive tubes (tubes showing gas formation) was recorded as follows: For sample A, the positive tube pattern was 2:2:0 and for sample B the positive tube pattern was 2:2:1. The corresponding MPN values were determined based on the number of positive tubes, as shown in Table 3.

Table 3. Most Probable Number (MPN) index for water sample tubes.

Samples Area	Positive 10mL	Positive 1mL	Positive 0.1mL	MPN Index / 100mL	Lower 95% CL	Upper 95% CL
Sample A (Classes)	2	2	0	21	4	47
Sample B (Hostel)	2	2	1	28	10	150

Frequency of Occurrence of Identified Bacteria

To further understand the microbial diversity in Kebbi State University of Science and Technology Aliero reservoir water, a frequency analysis of the identified bacterial species was conducted. This analysis details the number of occurrences for each bacterium identified, along with their respective frequencies as a percentage of the total bacterial isolates, as shown in Table 4.

Table 4. Frequency of occurrence of identified bacteria in KSUSTA reservoir water.

Identified Bacteria	Number of Occurrences (n)	Frequency (%)
Bacillus spp.	8	23.5%
Staphylococcus spp.	8	23.5%
Micrococcus spp.	5	14.7%
E. coli	5	14.7%
Enterobacter aerogenes	5	14.7%
Klebsiella spp.	3	8.8%
Total	34	100.0%

Explanation: The frequency (%) is calculated by dividing each bacterium's occurrences by the total isolate count (34) and multiplying by 100. For example, for Bacillus spp.: Frequency (%) = (8/34) × 100 = 23.5%.

Discussion

This research was conducted to assess the physicochemical and bacteriological quality of reservoir water in Kebbi State University of Science and Technology Aliero, with a focus on detecting coliform bacteria. The discussion section reviews the findings in relation to the study's objectives and supports these results with previous research. These samples were tested for different types of criteria viz. – physicochemical and bacteriological.

The physicochemical properties of the freshly collected water samples (which served as a starting point for these studies) are shown in Table 1. Some of the reservoir water samples did not comply with the standard limits for drinking water (WHO 2016). The temperature at sample A had the highest value of 27.0°C, while sample B had the least with 25.2°C. The pH value obtained from samples A and B fall within the range of 6.9 and 7.1 respectively; this indicates that the pH of the water from all samples is neutral to near-neutral in nature and falls within the normal range of 6.5–8.5. The generally low pH values obtained relative to pure alkaline environments might be due to the levels of free CO2 in the water samples, which may consequently alter the bacterial counts. This was also reported by Edema et al. (2001). The pH of water is extremely important. The fluctuations in optimum pH ranges may lead to an increase or decrease in the toxicity of substances in water bodies (Ali 1991).

Conductivity measured in µS/cm ranged from 156.1 ± 3.72 to 184.7 ± 9.58 µS/cm. Sample A (classes) had the lower conductivity of 156.1 ± 3.72 µS/cm, while sample B (hostel), located further away from some central disposal spots but higher in human traffic, had the higher conductivity of 184.7 ± 9.58 µS/cm as shown in Table 1. The alkalinity measurement mean was around 83.3 mg/L for sample A and 8.2 mg/L for sample B (Table 1). As already indicated, a pH less than 7 is defined as acidic and a pH greater than 7 as alkaline (Nelson 2002). Most points were near neutral to alkaline. Alkalinity relates to the concentration of calcium and carbonate, and high alkalinity has a bearing on the hardness of water. It was concluded that the alkalinity of water in the area was within an acceptable range at most points for general utility, though low in buffering capacity for Sample B.

Total dissolved solids is a measure of the level of dissolved solids in water and it influences the taste of drinking water. All the water supply samples studied met the recommended WHO (2017) guidelines in terms of total dissolved solids determination. Oyeku et al. (2001) and Nwosu and Ogueke (2004) made similar observations in the total dissolved solids determination of water in Lagos and Owerri metropolises, respectively.

Bacteriological analysis of reservoir water at different locations in Kebbi State University of Science and Technology Aliero focused on the presence of coliform bacteria, which are indicators of fecal contamination. Using the Multiple Tube Fermentation (MTF) method, the study identified significant levels of coliform bacteria, particularly fecal coliforms, which indicate possible contamination from environmental sewage or domestic runoff. The bacteriological analysis revealed Most Probable Number (MPN) values ranging from 4 to 47 coliforms per 100 mL in the confidence thresholds of sample A and 10 to 150 coliforms per 100 mL in sample B, with specific index values at 21 and 28 respectively. Sample B (hostel) showed higher contamination levels, likely due to increased exposure to pollutants or more significant environmental runoff and usage frequency.

The presence of coliform bacteria suggests that Kebbi State University of Science and Technology Aliero reservoir water is at risk of harboring pathogens such as Escherichia coli, which poses significant public health risks, especially for those using the water for domestic or

drinking purposes. This is in line with findings from Okafor et al. (2019), who also reported high levels of coliform bacteria in water bodies in regions with inadequate waste management practices. The consistent presence of gas formation in tubes during the MTF process confirms that the reservoir water is contaminated with coliform bacteria, making the water unsuitable for drinking without proper treatment. Previous studies, such as those by Bello and Ismail (2020), have similarly reported high MPN values in water sources exposed to runoff and domestic waste. Coliform bacteria, particularly Escherichia coli, are used as indicators because their presence suggests contamination from human or animal waste, which often contains harmful pathogens. The results from this study are consistent with the findings of Bello and Ismail (2020), who observed similar contamination in water bodies used for domestic purposes.

The study's results revealed significant levels of fecal coliform indicators, confirming that the water is unsuitable for direct human consumption without proper treatment. The frequency and percentage of occurrence of total coliforms identified from the reservoir water samples revealed that *Bacillus spp*. and *Staphylococcus spp*. had the highest frequency of occurrence at 8 (23.5%), followed by *Micrococcus spp*., E. coli, and Enterobacter aerogenes with 5 (14.7%) each, and the bacterium with the least frequency of occurrence was *Klebsiella spp*. with 3 (8.8%). The presence of enteric bacteria like E. coli can be attributed to fecal and municipal waste contamination, which may constitute a health hazard to humans and domestic animals. A similar conclusion was drawn by Lobina et al. (2015), who isolated *Escherichia coli* and Klebsiella species from water that was intended for human consumption. This suggests that water from these sources may pose health risks to consumers and is unsuitable for direct human consumption without treatment.

CONCLUSION

This study showed that the physicochemical parameters of the reservoir water were generally within the WHO permissible limits for drinking water. However, bacteriological analysis revealed the presence of coliform bacteria, including *E. coli*, indicating microbial contamination of the water. Sample A showed slight contamination, whereas Sample B exhibited higher bacterial contamination and may pose health risks if consumed without treatment. Therefore, the reservoir water is unsuitable for direct consumption and requires proper treatment and regular monitoring to ensure its safety for domestic use.

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